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Ecological correlation between aquatic vegetation and freshwater fish populations in Perak River, Malaysia

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Abstract. *Ismail SN, Abd Hamid M, Mansor M. 2018. Ecology, diversity and seasonal distribution of wild mushrooms in a Nigerian tropical forest reserve. Biodiversitas 19: 279-284.* Aquatic plants play a crucial role in an aquatic ecosystem partly because these plant communities provide suitable habitats and food items to other aquatic organisms especially fish. Many fish communities use vegetation as breeding sites, nurseries and refuges for their juveniles. Therefore, this study was conducted to provide baseline data on the correlation between the aquatic plants and freshwater fishes in Perak River. Based on the findings, the abundance of aquatic plant influences the growth and health of the fish. Habitats with moderate amounts of aquatic vegetation provide the optimal environment for many fish and hence, increase the fish diversity, feeding, growth, and reproduction. In contrast, both limited and excessive vegetation may decrease fish growth rates at 75% to 85% of plant community coverage. The recent trip along the Perak discloses the presence of these aquatic plants at certain habitats. There is a positive correlation between aquatic plants and freshwater fish. The association between aquatic plants and fish assemblages has been documented in scientific studies with the conclusion that moderate plant densities could enhance the fish diversity, feeding, growth, and reproduction.

Keywords: Ecological correlation, aquatic plant, fish populations, diversity, Perak River

INTRODUCTION

Perak River is the 'River of Life' for Perak State in Malaysia. Since decades ago, it has played an important role in providing water, food resources, transportation, agriculture, industries and cultural values (Zainudin 2005). Perak River is the second longest river in Peninsular Malaysia, it starts from the north-western corner of the state, flows south to Teluk Intan, where it bends westward and into the Straits of Malacca. The river divides the state into two nearly equal halves and thus forms its natural backbone; this river of life is special in many ways.

Worldwide, out of 285 studies on aquatic plants and freshwater fishes as cited from ISI Web of Knowledge provided from Universiti Sains Malaysia (USM), there were only three studies focusing on the correlation between the aquatic plants and freshwater fishes by Ricciardi and Kipp (2008), Lei et al. (2013), and Siniscalchi and Nikora (2013). Based on the available literature, approximately 300 species of the freshwater fishes and 235 species of aquatic plants are present in the aquatic ecosystems of Malaysia (Burkill 2002; Chong et al. 2010).

Aquatic plants grow partially or completely in the littoral zone. The littoral zone is the area where the light penetration is sufficient to support the plant growth (Krischik et al. 1997). There are three groups of plants that grow in littoral zones namely emergent plants, floating-leaved plants, and submerged plants. Emergent plants that inhabit the shallowest water are rooted in the sediment with their leaves extending above the water's surface. The common examples of plants of this zone are *Sagittaria sinensis* and *Phragmites communis* (Whetstone 2009). Floating-leaved species that grow at intermediate depths are rooted in the sediment, but some are free-floating with roots that hang unanchored in the water column. The common species belong to this group are water lily *Nymphaea* and sacred lotus *Nelumbo*. Submerged plants that inhabited the deepest fringe of the littoral zone are rooted in the sediment. Their growth occurs entirely within the water column. The examples of the plants are *Hydrilla verticillata, Najas minor, Chara vulgaris* and *Ceratophyllum demersum* (Goel 2006).

Aquatic plants have an integral role in the lake's ecology. Floating-leaf and submerged plants provide nutrients for animals like fish, insect larvae, snails, and other invertebrates. These plants also offer shelter for organisms that inhabit or are dependent on the body of water (Wagner 2004). Emergent plants are rooted in the lake floor and penetrate the water surface. These plants help protect shorelines and assist in stabilizing particles within the sediment, preventing the water clarity from deteriorating (Krischik et al. 1997).

Apparently, the correlation between plant and fish seems to provide a crucial relationship in natural ecosystems since the vegetation could influence the fish diversity, feeding, growth, and reproduction. Consequently, there are certain roles that have been provided by plant densities with the presence in desired abundance. However, to date, there has been no evaluation of this correlation featuring Perak River. To our knowledge, this is the first report on the correlation between the aquatic plants and freshwater fishes in this important river and will thus contribute to the development of a comprehensive baseline data of freshwater fishes in this region. Thus, the objective of the present study was to provide baseline data on the correlation between the aquatic plants and freshwater fishes in Perak River.

MATERIALS AND METHODS

This study was conducted at Perak River, Malaysia. Perak River basin is the second longest river (427km) in Peninsular Malaysia after Pahang River and has 15,151km^2 of catchment area (Ho 1994; Ali et al. 1988). Perak River flows from the Thai border passing through several towns before finally emptying into the Straits of Melaka as shown in Figure 1. The Perak River is the only river in Malaysia that has four dams built on the main river resulting in reservoirs formation from north to south which are Temengor Reservoir (water surface, 152 km^2), Bersia Reservoir (6km^2), Kenering Reservoir (41 km^2) and Chenderoh Reservoir (22 km^2) (Dahlen 1993).

A freshwater ecosystem consists of three basic types; lotic, lentic and wetlands. Lotic ecosystem is a faster-moving water body, such as streams and rivers. Then, lentic ecosystem is a slow-moving water body including pools, ponds and lakes and the last is wetlands are areas where the soil is saturated or inundated for at least part of time (David et al. 2005). Perak River comprises these entire three basic types of freshwater ecosystem. Lotic ecosystems of Perak River could be found at the upper part of this river, while the lotic ecosystems appear due to the ecological changes and human activities. Wetlands including swamp area and rice fields could be found in the lower zone to the estuary of this river.

This survey was done during April until July 2013. In this study, fish community and aquatic plants species were recorded at each district along Perak River from the upstream (Temengor Reservoir) to estuary (Bagan Datoh) (Table 1). Based on the field examination, it is hoped that certain ecological and biological theories could be formulated on this river system.

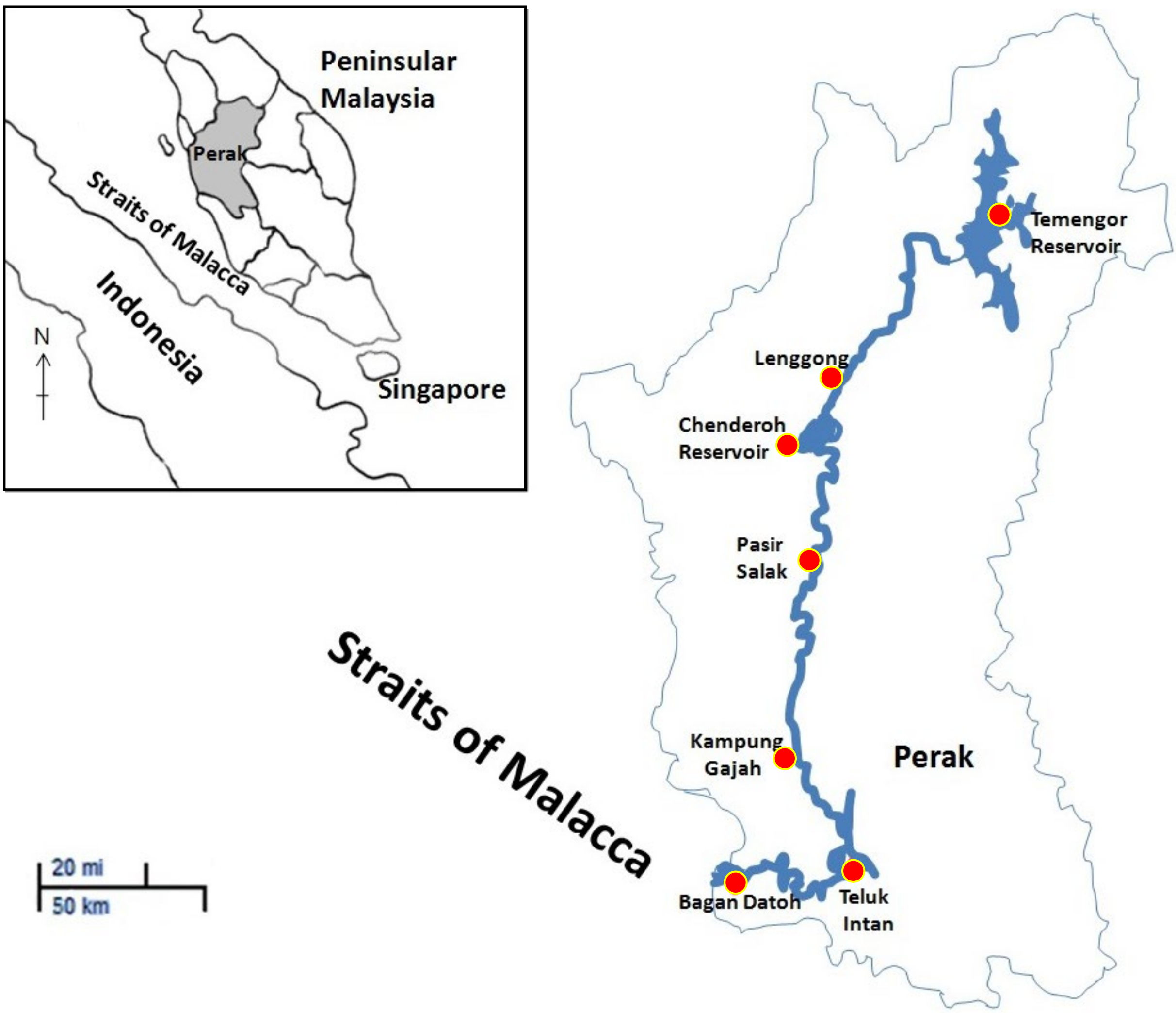

Figure 1. The Perak River map showing the sampling sites (Inset: Map of Peninsular Malaysia)

Table 1. The sampling location throughout the Perak River, Malaysia

No.	Section
I	Upper zone (Temengor Reservoir to Lenggong)
II	Middle Zone (Chenderoh Reservoir to Pasir Salak)
III	Lower Zone (Kampung Gajah to Teluk Intan)
IV	Estuary (Bagan Datoh to sea)

RESULTS AND DISCUSSION

Table 2 showed the species checklist of fish populations and aquatic plants that present in Perak River for each zone. There were 17 fish species and nine species of aquatic plant have been recorded. The most common fish species were *Cyclocheilichthys apogon, Hampala macrolepidota* and *Osteochilus hasseltii* in the upper zone, middle zone and lower zone of Perak River. *Clarias batrachus* could be found in every zone. For aquatic plant species, *Eichhornia crassipes* was observed to infest most of the surveyed zone whereas *Azolla pinnata* could only be found in the upper zone of Perak River.

The correlation between aquatic plant density and fish communities showed a sigmoid curve (Figure 2). At the beginning of the graph, a slow increase of aquatic plant density over fish communities was observed. After 30% of aquatic plant density, there was a rapid increase in fish communities. The population reaches its carrying capacity when aquatic plant density is about 75%~85%. The population decreases thereafter were due to the overload of aquatic plant density and intricate for fish survival.

Discussion

The results showed the optimum zone for higher fish population and aquatic plants species were in upper zone, middle zone and lower zone of Perak River. This is due to the environmental condition in the particular zone that favor the growth and reproduction rate of fish population (Gue´gan et al. 1998). Several environmental factors, such as the physicochemical characteristics of the water quality, topographical, hydrological regime and habitat destruction, could influence the species richness, diversity and species survival in aquatic ecosystems. The distribution and structure of fish community can be very diverse, depending on both biotic and abiotic conditions of the water body featuring the food availability and oxygen content (Gophen et al. 1998; Zakaria et al. 1999). Whereas, the estuary zone is likely to have more shrimps and marine fishes.

Generally, aquatic weed especially *Eichhornia crassipes* was frequently observed to float in the river, stick on the riverside substrate and colonize the riverbank area. Perak River and most of the rivers in West Coast States of Peninsular Malaysia were heavily infested with *E. crassipes* (Mansor 1996). This is concordance with this present study showing that *E. crassipes* were frequently found in all four zones. The need for good water quality cause *Azolla pinnata* could only be found in the upper zone with freshwater from the stream.

Table 2. Species checklist and the abundance recorded in each district across Perak River, Malaysia

Species	English name	Site I	Site II	Site III	Site IV
Fish species					
Barbonymus gonionotus	Java barb	**	*	***	-
Barbonymus schwanenfeldii	Tinfoil barb	**	**	***	-
Channa micropeltes	Giant snakehead	**	*	*	-
Channa striata	Snakehead *murrel*	*	*	**	**
Cyclocheilichthys apogon	Beardless barb	***	*	*	-
Hampala macrolepidota	Hampala barb	***	**	*	-
Hemibagrus nemurus	Asian redtail catfish	*	*	*	**
Oreochromis niloticus	Nile tilapia	*	*	**	-
Osphronemus goramy	Giant gourami	*	**	**	-
Osteochilus hasseltii	Hard-lipped Barb.	***	*	*	-
Oxyeleotris marmoratus	Marbled sand goby	**	*	*	*
Pristolepis fasciata	Malayan leaffish	*	*	*	-
Anabas testudineus	Climbing perch	-	*	**	*
Clarias batrachus	River catfish	*	*	**	*
Trichogaster pectoralis	Snakeskin gourami	-	-	**	*
Plotusus canius	Gray eel-catfish	-	-	-	**
Pangasius sp.	Pangasius catfish	-	**	**	*
Aquatic plants species					
Lemna minor	Duckweed	**	*	**	***
Polygonum barbatum	Knot grass	***	**	**	*
Eichhornia crassipes	Water hyacinth	***	***	***	***
Pistia stratiotes	Water lettuce	-	-	*	*
Neptunia oleracea	Water mimosa	*	***	***	*
Hydrilla verticillata	Oxygen weed	**	***	**	*
Salvinia molesta	Giant salvinia	*	*	***	***
Phragmites australis	Common reed	*	***	**	*
Azolla pinnata	Water velvet	*	-	-	-

Note: -: none, *: rare, **: moderate, ***: abundant

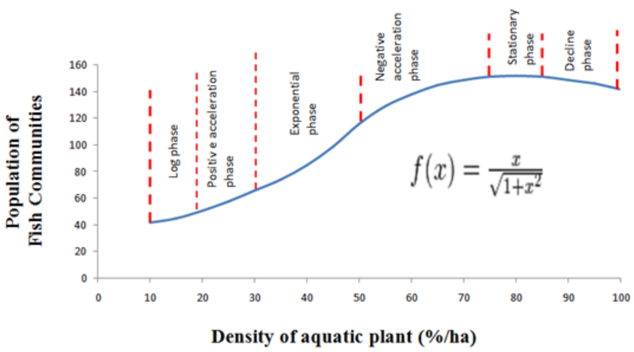

Figure 2. The correlation between the aquatic plants and freshwater fishes in Perak River, Malaysia

There is a positive correlation between aquatic plants and freshwater fishes. Aquatic plants benefit the fish population in many ways. However, the correlation depends on the aquatic vegetation. Younger and smaller fishes become more abundant as plant density increases (Borawa et al. 1979; Heck Jr. and Valentine 2006). Apparently, submerged vegetation is the key factor in the distribution and habitat use of adult fish. The finding suggested that aquatic plants' abundances trigger fish growth and condition, in which both limited and excessive plant growth may decrease fish growth rates (Haller 2009; Costa et al. 2010). Consequently, the dense mat of aquatic plants will choke out other aquatic organisms especially fish, leading to the collapse of the fish population.

Sites with vegetation generally have higher numbers of fish compared to non-vegetated areas. A literature search indicates that many juveniles and adult fishes have been reported present in habitats containing aquatic vegetation. The vegetated sites contain higher fish densities as compared to unvegetated areas (Borawa et al. 1979; Dibble et al. 1997; Meng et al. 2000). The plant beds structure is significant for fish reproduction. Many fish communities use vegetation as breeding sites, nurseries and important refuges for their juvenile since they provide minor shade, nesting and cover habitat for fishes (Krischik et al. 1997). In Perak River, there are high reproductive potentials at the sites with the aquatic vegetation or some form of plant structure such as *Phragmites communis* and *E. crassipes* (Whetstone 2009; Gettys 2009). There are advantages of nesting near the aquatic plants. Besides protecting from predators, vegetations could as well shelter the eggs and small fishes from the damage by the wave action (Haller 2009; Lynch 2009; Costa et al. 2010).

Aquatic plants can be a food source for herbivorous fishes since these plants provide little nutritional benefit. Generally, submerged aquatic macrophytes are moderately rich in protein and preferred by different herbivorous fish (Hasan and Chakrabarti 2009). The most commonly used macrophyte for fish feed is chara *Chara vulgaris*, hornwort *Ceratophyllum demersum*, oxygen weed *Hydrilla verticillata*, giant salvinia *Salvinia molesta*, water velvet *Najas minor*, water milfoil *Myriophyllum spicatum*, pondweeds *Potamogeton* sp. and duckweed *Lemna* sp. (Haller 2009; Lynch 2009; Nelson 2009; Costa et al. 2010; Velichkova and Sirakov 2013).

Apart from providing food, aquatic plant beds serve as refuge site for younger and smaller fishes. The leaves and stems of the plants provide the fishes substrates for attachment and protection from predators (Beckett et al. 1992; Petr 2000). This phenomenon seems to provide the answer to the higher abundance and diversity in vegetated areas as compared to the unvegetated area.

Furthermore, the sites of the plant communities in the water column and their morphology attract and influence the production of epiphytic invertebrates which then serve as prey for a variety of fishes especially Cyprinidae, Percidae, and Cyprinidontidae (Pípalová 2006; Meng et al. 2000; Hoover et al. 1988). Reduced plant densities due to weed management activities, boat traffic, and natural senescence may cause the loss of food sources for some fishes. However, the intricate bed structure of the plants such as the dense stem and foliage create visual and swimming barriers; hence, reduce foraging success of the fish due to the increased search time and reduced swimming velocities (Dibble et al. 1997).

For instance, small fishes prefer habitats with smooth cordgrass *Spartina alterniflora* (a shorter and less dense native species) to those with infestations of plants. However, the dense clumps of the macrophyte plant would detriment the fish community. Excessive plant growth reduces growth and condition of fish due to reduced foraging efficiency (Dibble et al. 1997; Meng et al. 2000). The sparse plant density increases the competition, resulting in slower growth rates of fish presumably by reducing caloric intake (Diehl 1993). However, stunted fish growth also occurred when plants occupied the entire water body especially in shallow systems (Haller 2009; Lynch Jr. 2009).

Aquatic plants are a vital contributor in maintaining stability within a lake's environment. In a limnological system, aquatic plants could help in producing oxygen, while simultaneously absorbing nutrients like phosphorus and nitrogen (Krischik et al. 1997; Hasan and Chakrabarti 2009). These plants could stabilize the sediment and help increase water clarity. However, the infestations of aquatic plant created several problems such as restricting the recreational and commercial activities and make boating, fishing, and activities impossible.

The undisturbed floating mats of aquatic vegetation seem to provide a perfect base to support the growth of other macrophytic plants, grasses or even small trees which further bind the floating mats together (Haller 2009). Consequently, the excessive populations of the plant such as water hyacinth *E. crassipes*, Giant salvinia *S. molesta,* water lettuce *Pistia stratiotes*, water mimosa *N. oleracea*, *Nymphaea* may overtake the natural flora, adversely resulting in serious ecological impacts which are associated with ecosystem changes such as alterations of soil properties, sedimentation rates, and fish habitat use and food webs (Paisooksantivatana 1993; Gettys 2009; Lynch Jr. 2009; Nelson 2009). From the result, 85% of plant communities' coverage could affect the fish population, while further infestation might result in adverse effects on the fish population. Other than that, water flow is greatly reduced and hence can impede irrigation and flood control efforts (Haller 2009). In Perak River, this issue should be highlighted since a series of hydroelectric dams have been built across this river which functions as hydroelectric power generators and flood control. The infestation of aquatic plants may bring severe problem since the plants can be stuck at the turbine system and make the dam function fail. However, there have been no reports on aquatic plants' infestation in Perak river.

In addition, there are studies concerning the submerged macrophytes control by herbivorous fish (Dall Armellina et al. 1999; Qiu et al. 2001; Ward et al. 2006). This herbaceous fish could be effective for aquatic weed control. Various herbivorous fish species, including tilapia species (*Tilapia zillii* and *T. rendalli*), Java barb *Barbonymus gonionotus*, giant gourami *Osphronemus gourami*, common barb *Puntius binotatus* and various strains of the common carp and grass carp *Ctenopharyngodon idella* have been recommended for aquatic weed control (Pípalová 2006). For instance, since grass carp feed on *Hydrilla verticillata* and *Ceratophyllum demersum*, hence this fish species could control the excessive plant species in a particular area.

In Perak River, certain fish species such as snakehead fish (*Channa striatus*) and climbing perch (*Anabas testudineus*) have utilized the root of *S. molesta* and the leaves of water mimosa *Neptunia oleracea* as their food source. Apparently, aquatic plant identification is still required for biological control since each fish species selectively control certain weed species while having no preference for other plants. These submerged macrophytes were taken either in fresh form or as a dried meal within a pelleted diet (Hasan and Chakrabarti 2009).

In conclusion, aquatic plant seems to benefit the fish community directly or indirectly. Besides serving as minor shade, nesting, refuge and cover habitat for fishes, the leaves or stem of the plant can be attractive and good foods to certain fish species. From this association, the role of aquatic plants as fish habitat and their value as a management tool in reservoirs then can be better defined. Nevertheless, the excessive growth of the macrophytic plant should be controlled which otherwise could detriment the fish and other invertebrate. It is critically vital to develop a comprehensive management plan to effectively control the excessive aquatic plants in water resources in order to prevent the biodiversity loss and lake ecosystem failure.

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